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**Key words:** Load, Global Positioning System, Physical Capacity

### **Introduction**

Fatigue is often described as the inability to maintain force or power output at the required level<sup>1</sup>. Whilst a number of models have been proposed to describe the mechanisms underlying reductions in work output, many of these may be considered to have acute and often transient performance limitations<sup>1</sup>. A major area of interest for researchers and practitioners alike is the influence of various longer term fatigue states on athletic performance (fatigue-recovery cycle timeline) and more specifically, discovering effective methods of assessing fatigue<sup>2</sup>. Specifically, the assessment of neuromuscular fatigue (NMF) via flight time : contraction time ratio (FT:CT) has been shown to be a useful tool to monitor fatigue status in elite Australian Football players<sup>2</sup>.

Recent studies have investigated the immediate physical consequence of team sport or simulated team sport running, demonstrating reductions in muscle strength and muscle activation<sup>3, 4</sup>. Furthermore, FT:CT from a single countermovement jump (CMJ) has also been shown to be suppressed for up to 72 hours post an elite Australian Football match<sup>2</sup>. An inability to recover neuromuscular function in accordance with the normal fatigue-recovery cycle may have implications on performance<sup>5</sup>. Currently it is unclear if a suppression of neuromuscular function (in the form of lower FT:CT) will impact on the physical activity profile of elite Australian Football players.

Recently, the importance of high intensity running (distance covered at > 15 km/h) to elite Australian Football performance has been demonstrated to positively influence performance at the beginning of the season and similar findings have been reported in elite soccer<sup>6-8</sup>. It has been established that this type of running is a discriminator of high and low performing teams

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within a competition level and between leagues of different standards<sup>9</sup>. Importantly, high intensity running in Australian Football is subject to an athlete's physical capacity specifically measured by yo-yo Intermittent Recovery Test (level 2) score (yo-yo IR2)<sup>8</sup>. A specific sequence (or domino effect) was established with yo-yo IR2 capacity affecting the amount of HIR  $\text{m}\cdot\text{min}^{-1}$  accumulated, which in turn influences the number of ball disposals gained in elite Australian Football<sup>8</sup>. This suggests that without affecting HIR  $\text{m}\cdot\text{min}^{-1}$ , yo-yo IR2 score does not (independently) affect performance. It has also been demonstrated that yo-yo performance does not significantly change across a competitive season in elite soccer<sup>10</sup>. Both soccer and Australian Football have reported similar exercise intensities, yet Australian Football involves approximately 10 minutes greater volume (90 vs. 100 minutes)<sup>7, 11</sup>. As is the case in soccer<sup>3</sup>, the match is the greatest training stimuli during the competition phase. Therefore, substantial alterations in high intensity running throughout the season are likely due to the influence of fatigue rather than a change in yo-yo IR2.

Match exercise intensity is generally measured via derivatives of distance, gathered from micro-technology such as Global Positioning Systems (GPS), but recently has also been measured by accelerometers<sup>12</sup>. An accelerometer measures the tri-axial change of inertia (acceleration) at 100Hz making it much more sensitive to subtle movements than GPS that measures global displacement at only 1 – 10 Hz. The summation of the tri-axial accelerations is determined as "Load<sup>TM</sup>" and a detailed description and calculation of Load<sup>TM</sup> has been presented by Boyd et al.<sup>12</sup>. Unlike GPS, it is unclear if the accumulation of accelerometer Load<sup>TM</sup> is influenced by physical capacity (yo-yo IR2), provides any indication of physical performance of Australian Football players, or is sensitive to NMF in the elite Australian Football population.

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The aforementioned factors (physical capacity, match exercise intensity and neuromuscular fatigue) have all been found to influence elite Australian Football performance<sup>5, 8</sup>. However, the manner in which these variables interact to influence elite Australian Football performance across an entire season remains vague. Therefore, this study aimed to identify: 1) if NMF influences Australian Football performance by affecting associations between yo-yo IR2 and performance (coaches' votes and number of ball disposals) across an entire season, 2) if NMF influences the relationship between yo-yo IR2 and match exercise intensity ( $\text{HIR m}\cdot\text{min}^{-1}$  and  $\text{Load}^{\text{TM}}\cdot\text{min}^{-1}$ ) and 3) if NMF affects the relationship between  $\text{Load}^{\text{TM}}\cdot\text{min}^{-1}$  and other reliable exercise intensity measures ( $\text{m}\cdot\text{min}^{-1}$  &  $\text{HIR m}\cdot\text{min}^{-1}$ ). It is hypothesised that NMF will alter the relationships between physical capacity, match exercise intensity and match performance in elite Australian Football players.

### Methods

This study was a prospective longitudinal design. Common Australian Football performance measures were used as dependant variables, whilst the yo-yo IR2 test as a measure of physical capacity was used as the independent variable. Match exercise intensity measures were included as mediators (link between dependant and independent variables) and NMF was included as a conditional variable (moderator) (see Figure 4.1 and Appendix A).

Seventeen elite Australian Football players with a mean ( $\pm\text{SD}$ ) stature of  $187.6 \pm 7.3$  cm, mass of  $86.5 \pm 8.7$  kg and age of  $22.3 \pm 3.3$  years provided data for this research. Informed consent was gathered prior to the commencement of the studies. Ethical approval was obtained by the University Research Ethics Committee. Participants were informed of the risks of the study in person and writing, signed an informed consent document prior to the beginning of data collection and were free to withdraw from the study at any time.

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The participants were professional elite players participating in the Australian Football League. Participants were completing between seven and nine training sessions per week including various sessions (such as recovery, skills, weights, flexibility and matches) and a day off mid-week.

All participants completed the yo-yo IR2 test (independent variable) before the start of the season, were selected to play for the first grade team, provided match exercise intensity (mediator) at least once during the season (gathered via GPS device during match), performed a single counter movement jump to obtain FT:CT ratio prior to the upcoming match (moderator/conditional variable) and had match performance records (dependent variables: number of ball disposals and coaches' votes) collected post match from any of the 22 matches of the competitive season. Each match was treated as an independent sample. A total of 37 samples were obtained with subjects providing between 1 and 4 samples each.

The players performed the single countermovement jump on a force plate (400 series force plate; Fitness Technology, Adelaide, Australia) operated by manufacturer software (Ballistic Measurement System, Fitness Technology). The ratio of FT:CT was calculated using custom software (TLAD Athlete Solutions, Melbourne, Australia). The assessment of FT:CT was conducted according to previously established protocols, which has been demonstrated as both valid and reliable (CV = 8%) in elite Australian Football players<sup>5, 13</sup>. All subjects were familiarised with the procedures during four practice trials. Baseline testing was calculated as the four week mean leading into the first match (conducted during the taper of the pre-competition phase) of the 22 match season which allowed a fatigue free competition phase baseline. Weekly tests were conducted a minimum of 96 h post match (the day after the day off), which according to previous work would be long enough to allow a return to baseline

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values if athletes followed the expected fatigue-recovery cycle<sup>2</sup>. Players performed a standardised warm up including 2 minutes of aerobic exercise, dynamic flexibility movements and 3 practise jumps prior to collection of weekly data in accordance with established protocols<sup>2</sup>. Testing procedures were conducted at the same time of day 0900 – 1000 h. Weekly values were calculated as a percentage of the baseline and then categorised as *fatigued* or *normal* based on the natural biological fluctuation of 8% in this population<sup>6</sup>.

All participants had their match exercise intensity recorded by a portable GPS unit sampling at 5 Hz whilst the internal accelerometer (housed inside the same GPS device) sampled at 100 Hz (MinimaxX, Team 2.5, Catapult Innovations, Scoresby, Australia). Match exercise intensity and performance measures were gathered from all 22 matches of a single season. Global positioning system data was downloaded post match using manufacturer specific software (Logan Plus v. 4.4.0) for analysis.

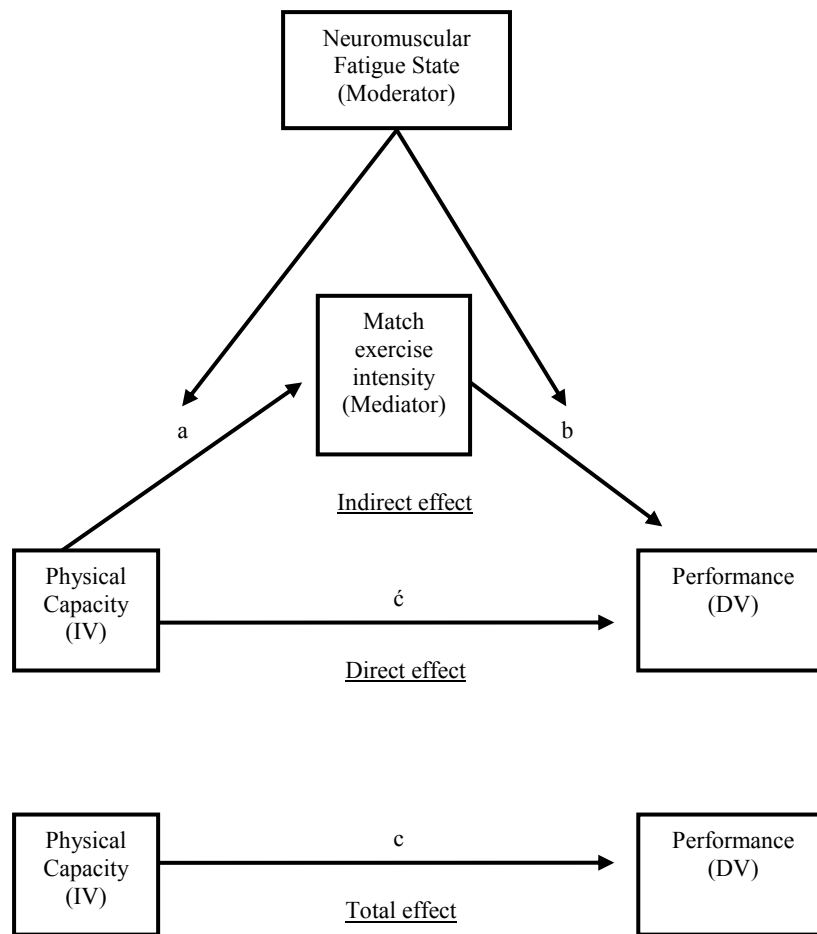
The participants were analysed for hypohydration status one day prior to all matches and on the morning of match day to ensure dehydration would not affect the match exercise intensity or performance. Players also followed a nutrition plan directed by a sports dietician throughout the season to ensure they were appropriately fuelled for optimal performance. Match exercise intensity was only recorded for the on-field playing duration of each participant. To reduce the likelihood of reporting artificially high match exercise intensities, match activity profiles were only accepted for analysis if the participant played  $\geq 70\%$  of total match time and absolute variables were divided by the on field duration<sup>14</sup>. Variables collected from the GPS units were distance travelled per minute ( $\text{m} \cdot \text{min}^{-1}$ ), distance travelled at high intensity per minute ( $\text{HIR m} \cdot \text{min}^{-1}$ ) where  $\text{HIR m}$  = distance travelled above  $15 \text{ km} \cdot \text{h}^{-1}$  and accelerometer Load<sup>TM</sup> per minute ( $\text{Load}^{\text{TM}} \cdot \text{min}^{-1}$ ), as described previously<sup>8</sup>. These variables

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have been tested for reliability and validity; high intensity distance (striding and sprinting) CV = 9.0–11.9% (activity dependent), validity range -6.2–4.6% (activity dependent)<sup>15</sup> whilst Load<sup>TM</sup>·min<sup>-1</sup> has shown a CV of < 2%<sup>12</sup>.

The participants' number of ball disposals were collected by a commercial statistical analysis company (Champion Data<sup>®</sup>, South Bank, Australia). Champion data have been reported to have a 99% accuracy rate for match statistics<sup>16</sup>. Coaches' votes were also collected post match from five assistant coaches. Coaches rated every players performance within 60 mins post match on a 1 – 5 scale (1 = poor performance – 5 = excellent performance). An aggregate score was given to each player per match similar to previous protocols<sup>5, 17</sup>. The aggregate score has been shown to have acceptable internal consistency (Cronbach's  $\alpha$  ranging 0.88 – 0.92)<sup>8</sup>.

To investigate the interaction of the variables, moderated-mediation model 5 was employed, where the moderator (FT:CT) interacts with both the *a* and *b* mediation paths with bootstrap resampling method as described in previous work (see Figure 4.1)<sup>18</sup>. A comprehensive description of mediation and moderation analysis has been provided by others<sup>18</sup>.



**Figure 4.1:** The interaction being tested in mediation-moderation analysis. IV represents the independent variable, DV represents the dependant variable. The indirect effect is the effect the IV has on the DV through the mediator (a X b). The direct effect ( $\hat{c}$ ) is the effect the IV has on the DV controlling for the mediator. The total effect (c) is the effect of the IV on the DV not controlling any other variable. The moderator is the conditional variable separating the analysis into 2 mediation analyses (normal and fatigued states).

Individual FT:CT were categorised as either *normal* or *fatigued* from baseline based on a change greater than the biological fluctuation of 8% reported in previous literature<sup>13</sup>. Moderation-Mediation effect was analysed in SPSS v.17 (SPSS Inc., Chicago, USA) using macro and syntax from Preacher, Rucker and Hayes (moderation-mediation), using a significance criteria of  $<0.1$ <sup>18</sup>. This significance level was chosen as the standard  $<0.05$  significance criteria may be too conservative for detecting important practical changes in the elite sport environment<sup>8, 19</sup>.



Once a difference in the indirect effect was identified (based on significance of indirect effect), the individual relationships were separated for *normal* and *fatigue* FT:CT and analysed using a magnitudes based approach. This was done by calculating a Pearson's correlation coefficient and the 75% likelihood of a change in correlation exceeding 0.1 using a custom Excel spreadsheet<sup>21, 22</sup>. A qualitative criteria was given to the per cent likelihood of a practically meaningful correlation ( $> 0.1$ ) and was categorised as most unlikely (0.5 – 4.9%), very unlikely (5 – 24.9%), unlikely (25 – 74.9%), possible (75 – 94.9%), likely (95 – 99.5%) and most likely (100%)<sup>22</sup>. In addition, variables were log transformed to reduce bias due to non-uniformity of error and each path was analysed for the magnitude of the difference in mean of the dependant variable (DV), after controlling for the independent variable (IV) in both *normal* and *fatigued* states<sup>22</sup>. A practically important difference was determined as a  $> 75\%$  chance of the ES exceeding 0.2<sup>23</sup>. The magnitude of the change in the ES (when controlled for change in dependent variable) was classified as negligible (0.0 – 0.19); small (0.2 – 0.59); moderate (0.6 – 1.1); large (1.2 – 1.9); very large ( $> 2.0$ )<sup>23</sup>.

### Results

The mean  $\pm$ SD of the yo-yo IR2, HIR  $\text{m}\cdot\text{min}^{-1}$ , Load<sup>TM</sup> $\cdot\text{min}^{-1}$ , number of ball disposals and coaches' votes were  $1028 \pm 190$  m,  $38.8 \pm 11.6$   $\text{m}\cdot\text{min}^{-1}$ ,  $15.7 \pm 3.1$  arbitrary units $\cdot\text{min}^{-1}$ ,  $16.5 \pm 6.0$  disposals and  $11.5 \pm 4.1$  votes respectively. Yo-yo IR2 showed a significant indirect effect on ball disposals through HIR  $\text{m}\cdot\text{min}^{-1}$  in both *normal* ( $n = 20$ ) and *fatigued* ( $n = 17$ ) FT:CT state (Table 4.1). Yo-yo IR2 showed a significant indirect effect on coaches' votes through Load<sup>TM</sup> $\cdot\text{min}$  in only the *normal* FT:CT group.

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**Table 4.1:** The indirect effect of the independent variable (X) and mediator (M) on the dependant variable (Y) when separated for flight time contraction time ratio (FT:CT).

<b>X→M→Y</b>	<b>Boot sample (n)</b>	<b>Normal FT:CT</b>		<b>Reduced FT:CT</b>	
		<b>Boot indirect effect</b>	<b>Boot p-value</b>	<b>Boot indirect effect</b>	<b>Boot p-value</b>
<b>Yo-yo IR2→HIR m·min<sup>-1</sup>→ball disposals</b>	3000	0.019 (0.006)	0.00*	0.022 (0.011)	0.03*
<b>Yo-yo IR2→ HIR m·min<sup>-1</sup>→coaches' votes</b>	3000	0.003 (0.008)	0.71	-0.122 (0.012)	0.31
<b>Yo-yo IR2→ Load<sup>TM</sup>·min<sup>-1</sup> →ball disposals</b>	3000	0.005 (0.006)	0.34	-0.001 (0.004)	0.77
<b>Yo-yo IR2→Load<sup>TM</sup>·min<sup>-1</sup> →coaches' votes</b>	3000	0.007 (0.004)	0.09*	-0.001 (0.004)	0.77

Normal = > 92% of baseline and Reduced = < 92% of baseline. Indirect effects are represented by regression coefficients with standard errors in parentheses. *Boot* indicates the results are derived from bootstrap resampling technique. \* indicates significance at the 0.1 level.

Table 4.2 illustrates the strength of the change in isolated relationships. All interactions showed meaningful positive correlations in the *normal* FT:CT state. However, only the relationship between yo-yo IR2 and Load<sup>TM</sup>·min maintained a meaningful positive correlation in a *fatigued* FT:CT state. Furthermore, the changes in correlations are all > 75% likely to be greater than the criteria  $r = 0.1$  representing a practically important change in relationship from the *normal* to *fatigued* FT:CT state. When the paths were isolated, the *a* path (yo-yo IR2 and Load<sup>TM</sup>·min<sup>-1</sup>, see Figure 4.1) showed no mean difference in Load<sup>TM</sup>·min between *normal* and *fatigued* FT:CT (adjusted for yo-yo IR2). However, there was a mean reduction in coaches' votes in the fatigued FT:CT state (adjusting for either yo-yo IR2 or Load<sup>TM</sup>·min<sup>-1</sup>).

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**Table 4.2:** Changes in mean and correlation when separated into normal and fatigued groups.

IV→DV	Normal FT:CT			Fatigued FT:CT			Difference	
	n	Adjusted mean of DV	r	n	Adjusted mean of DV	r	Difference in adjusted mean after log transformation (ES)	Δr
Yo-yo IR2 → Load <sup>TM</sup> ·min <sup>-1</sup>	20	15.4 (1.81)	0.77±0.17 very likely	17	16.3 (3.7)	0.33±0.38 likely	0.33±0.57 unclear	0.44±0.26 very likely
Load <sup>TM</sup> ·min <sup>-1</sup> →coaches' votes	20	12.83 (3.34)	0.51±0.27 very likely	17	10.5 (4.5)	-0.22±0.4 possible	-0.67±0.56 large-trivial	0.73±0.43 very likely
Yo-yo IR2→coaches' votes	20	12.41 (3.53)	0.38±0.33 likely	17	10.28 (4.5)	-0.17±0.4 possible	-0.60±0.56 moderate-trivial	0.54±0.48 likely
Yo-yo IR2→coaches' votes (controlling Load <sup>TM</sup> ·min <sup>-1</sup> )	20		-0.03±0.38 unclear	17		-0.1±0.41		0.07±0.54 unclear

Means of the dependant variable (DV) are represented by adjusted mean for differences in independent variable (IV) ± standard error of the estimate. Pearson correlation coefficients (r) are presented with ± 90% confidence intervals. Differences in means are represented by Cohen's effect size (ES) ± 90% confidence interval with qualitative descriptor whilst magnitude of difference in correlations (Δr) are represented by r ± 90% confidence interval and qualitative descriptor.

Table 4.3 shows that the relationship between  $\text{Load}^{\text{TM}} \cdot \text{min}^{-1}$  and  $\text{m} \cdot \text{min}^{-1}$  does not change in the presence of NMF, nor does the mean of  $\text{m} \cdot \text{min}^{-1}$  change (adjusting for  $\text{Load}^{\text{TM}} \cdot \text{min}^{-1}$ ). Furthermore, the relationship between  $\text{Load}^{\text{TM}} \cdot \text{min}^{-1}$  and HIR  $\text{m} \cdot \text{min}^{-1}$  was meaningfully reduced in the fatigued state. In addition, there was a practically important difference in HIR  $\text{m} \cdot \text{min}^{-1}$  between the *normal* and *fatigued* groups (adjusting for changes in  $\text{Load}^{\text{TM}} \cdot \text{min}^{-1}$ ).

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**Table 4.3:** The difference in mean and in relationship between Load<sup>TM</sup> per minute (Load<sup>TM</sup>·min<sup>-1</sup>) and distance per minute (m·min<sup>-1</sup>) and Load<sup>TM</sup>·min<sup>-1</sup> and distance at high intensity per minute (HIR·min<sup>-1</sup>) when separated into Normal and Fatigued groups.

IV → DV	Normal FT:CT			Fatigued FT:CT			Difference	
	n	Adjusted mean of DV	r	n	Adjusted mean of DV	r	Difference in adjusted mean after log transformation (ES)	Δr
Load <sup>TM</sup> ·min <sup>-1</sup> → m·min <sup>-1</sup>	20	137.8 (7.8)	0.76±0.17 most likely	17	133.7 (12.5)	0.58±0.29 very likely	-0.37±0.56 unclear	0.18±0.27 unclear
Load <sup>TM</sup> ·min <sup>-1</sup> → HIR m·min <sup>-1</sup>	20	41.5 (7.2)	0.74±0.19 most likely	17	36.9 (9.9)	0.31±0.38 likely	-0.47±0.56 moderate-trivial	0.43±0.29 very likely

Means of the dependant variable (DV) are represented by adjusted mean for differences in independent variable (IV) ± standard error of the estimate. Pearson correlation coefficients (r) are presented with ± 90% confidence intervals. Differences in means are represented by Cohen's effect size (ES) ± 90% confidence interval with qualitative descriptor whilst magnitude of differences in correlations (Δr) are represented by r ± 90% confidence interval and qualitative descriptor.

### Discussion

This study hypothesised that NMF would affect relationships between physical capacity, match exercise intensity and elite Australian Football performance. The results highlight four novel findings that support this hypothesis. First FT:CT influences (moderates) the effect of yo-yo IR2 and Load<sup>TM</sup>·min<sup>-1</sup> on coaches' votes (ES  $-0.6 \pm 0.56$  and  $-0.67 \pm 0.56$  reduction in the fatigued state respectively). Secondly, we have validated Load<sup>TM</sup>·min<sup>-1</sup> as a useful match exercise intensity measure in Australian Football. Finally, the presence of NMF appears to alter the way in which Load<sup>TM</sup>·min<sup>-1</sup> is produced. However, NMF did not influence the relationships between yo-yo IR2, HIR m·min<sup>-1</sup> and number of ball disposals<sup>8</sup>.

This study identified a reduction in FT:CT exceeding the 8% CV has a direct negative effect on the relationship between Load<sup>TM</sup>·min<sup>-1</sup> and coaches' votes. The mechanics to produce the same output (i.e. Load<sup>TM</sup>·min<sup>-1</sup>) appear to be altered with reductions in FT:CT<sup>13</sup>, and this change is perceived negatively by coaches. This is a similar finding to previous research that found a small correlation between raw change in FT:CT from baseline and coaches' votes one week prior to a match in Australian Football players of the same level of competition as the current study<sup>5</sup>. A potential hypothesis is that Australian footballers may become inefficient in the production of a given Load<sup>TM</sup>·min<sup>-1</sup>. For example, they may be slower to accelerate, thus arrive late to contests or have a reduced ability to evade an opponent. This may result in players achieving the same Load<sup>TM</sup>·min<sup>-1</sup> but in a different and undesirable manner (i.e. greater subtle lateral or vertical movements in a NMF fatigued state to produce a given Load<sup>TM</sup>·min<sup>-1</sup>).

A meaningful change in relationship between Load<sup>TM</sup>·min<sup>-1</sup> and HIR m·min<sup>-1</sup> ( $\Delta r = 0.43 \pm 0.29$ ), and not Load<sup>TM</sup>·min<sup>-1</sup> and m·min<sup>-1</sup> ( $\Delta r = 0.18 \pm 0.27$ ) in the fatigued state also suggests

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an alteration in activity profile in a fatigued state. Previously, very high correlations have been observed between Load<sup>TM</sup> and distance ( $r^2 = 0.90$ )<sup>24</sup>. Although, this study shows that this particular relationship remains stable in the presence of NMF, it is clear that the relationship between Load<sup>TM</sup>·min<sup>-1</sup> and HIR m·min<sup>-1</sup> is altered. A potential explanation for this is that players alter the way they accumulate Load<sup>TM</sup> and this alteration is perceived poorly by coaches. A movement efficiency concept in Australian Football has been suggested previously, with more experienced players obtaining a higher number of disposals for a given HIR m·min<sup>-1</sup> than less experienced players<sup>8</sup>.

Another important finding from this study was the change in correlation between yo-yo IR2 and Load<sup>TM</sup>·min<sup>-1</sup> from normal to fatigued states ( $\Delta r = -0.44 \pm 0.26$ ). The difference in correlation between the two conditions suggests that in the fatigued state, the importance of yo-yo IR2 to the production of Load<sup>TM</sup>·min<sup>-1</sup> is reduced. Critically, this occurs without a practically important change (ES  $0.33 \pm 0.57$ ) in mean Load<sup>TM</sup>·min<sup>-1</sup> when adjusted for yo-yo IR2 performance, regardless of fatigue status. This appears to confirm the notion that elite Australian Football players are able to produce a similar output (as measured by Load<sup>TM</sup>·min<sup>-1</sup>) when fatigued, however the movements contributing to the accumulation of Load<sup>TM</sup>·min<sup>-1</sup> are less dependent on capacity (i.e. produced at a lower intensity).

As HIR m·min<sup>-1</sup> (when corrected for yo-yo IR2) was not altered by NMF, it is also plausible performance (as assessed by coaches) is influenced more heavily by effectiveness than total work output. Players experiencing NMF may continue to have high output (i.e. HIR m·min<sup>-1</sup> and Load<sup>TM</sup>·min<sup>-1</sup>) but undergo changes to mechanical efficiency that result in movement patterns viewed as ineffective by coaches. Players with NMF may be able to maintain overall high intensity running performance but actually perform more work at lower levels of this

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intensity band (i.e.  $< 24 \text{ km}\cdot\text{h}^{-1}$ ). Neuromuscular fatigue present prior to elite handball matches has also been coupled with reductions in sprint performance, and this supports the concept that NMF may reduce the ability to perform maximum intensity efforts<sup>25</sup>.

Interestingly, a mediation relationship was observed between yo-yo IR2 and number of disposals through HIR  $\text{m}\cdot\text{min}^{-1}$  across an entire season, which is a similar finding to previous research that investigated this mediation during the first half of a season<sup>8</sup>. We hypothesised that NMF may have disrupted this relationship, however yo-yo IR2 remains associated with number of disposals via HIR  $\text{m}\cdot\text{min}^{-1}$ . Therefore, variability in HIR  $\text{m}\cdot\text{min}^{-1}$  throughout a season may be a result of factors other than NMF, such as playing conditions, strategic or psychological factors, or other forms of acute or cumulative fatigue. Regardless of NMF status, the current data suggests that the yo-yo IR2 test provides a strong indication of the overall HIR  $\text{m}\cdot\text{min}^{-1}$  that can be performed by players during the entire season.

Although this study has high ecological validity, some limitations were apparent with the study design and should be noted. For example, the psychological state of the players prior to the match was not tested prior to each performance. Whilst real world elite sporting performance imposes some limitations on the ability to completely control the environment, the results of the current research are clear and unlikely to have been influenced by extraneous factors. As a result, there are clear practical implications for performance.

### **Conclusion**

This study is the first to demonstrate the effect of NMF on Australian Football performance by negatively influencing the relationships between yo-yo IR2 and coaches votes through

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Load<sup>TM</sup>·min<sup>-1</sup>. Furthermore, it was identified yo-yo IR2 can reflect the number of ball disposals through-out the entire season via HIR m·min<sup>-1</sup>, regardless of NMF. Additionally, the results of this study validates Load<sup>TM</sup>·min<sup>-1</sup> as a useful exercise intensity measure in elite Australian Football. It also suggests that NMF status can affect the association of Load<sup>TM</sup>·min<sup>-1</sup> with other match exercise intensity measures.

### **Practical Implications**

- Load<sup>TM</sup>·min<sup>-1</sup> and HIR m·min<sup>-1</sup> influence performance and should be used for the assessment of exercise intensity in elite Australian Football players.
- Neuromuscular fatigue via FT:CT influences performance and should be routinely conducted in elite Australian Football.
- Yo-yo IR2 tests provide an indication of the HIR m·min<sup>-1</sup> a player can perform throughout the entire season and should be included in an Australian Football testing battery.

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